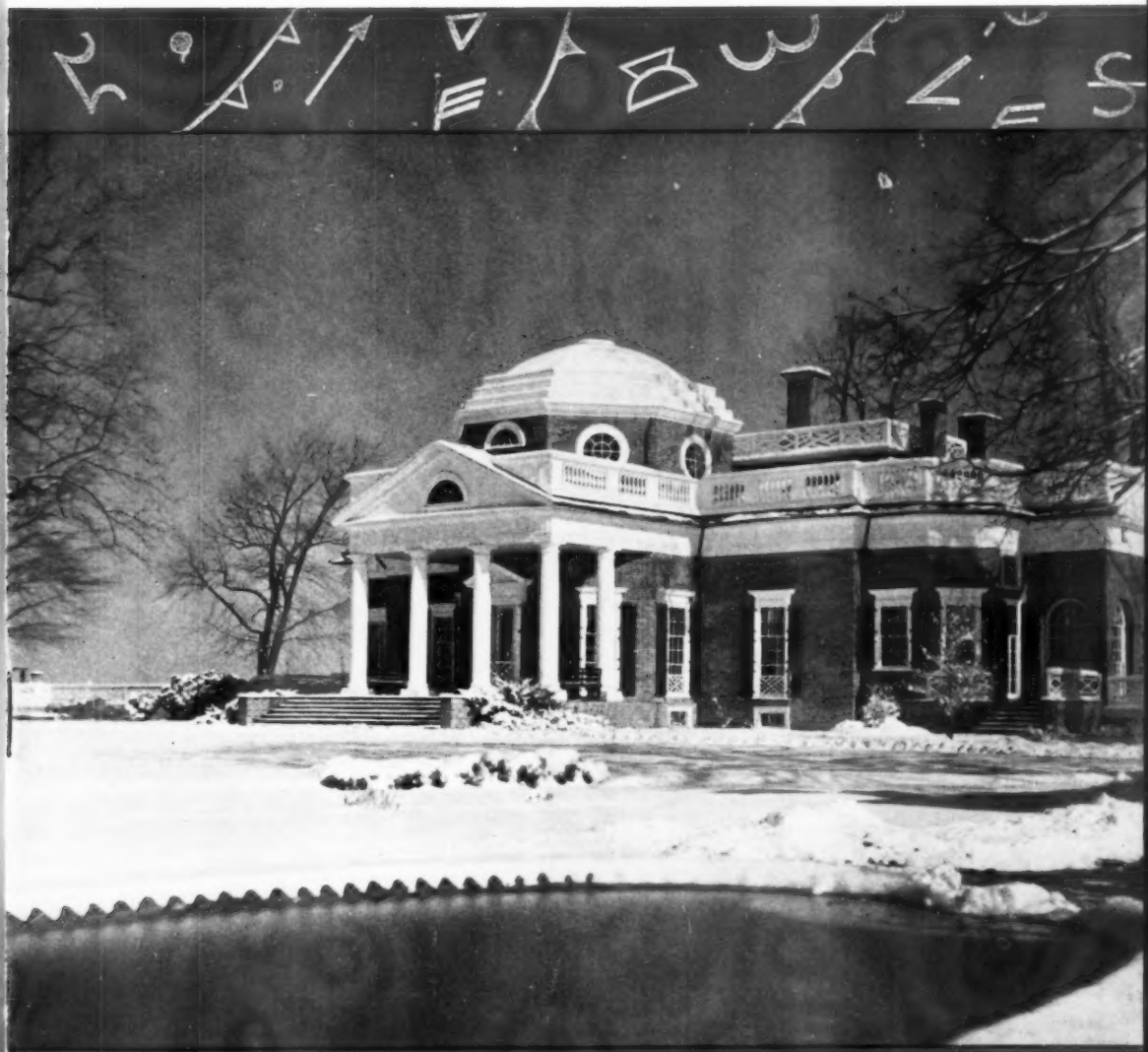
Weatherwise



Volume 10, Number 6 December 1957

"SOME PEOPLE ARE WEATHERWISE BUT MOST ARE OTHERWISE"—BENJAMIN FRANKLIN

WEATHERWISE

THE MAGAZINE ABOUT WEATHER

DAVID M. LUDLUM, *Editor* HENRY W. BULKLEY, *Associate Editor*

A Letter from Nairobi

ON the day that this issue of *Weatherwise* was in editorial throes, two unexpected, but none the less locally pleasing, things occurred. Our football team won the Ivy League championship amid meteorological conditions (snowflakes the size of silver dollars) that would have fascinated Messrs. Bentley, Schaefer, and Nakaya. And a letter arrived from Nairobi, Kenya, asking for an additional copy of a recent article on forecasting.

That *Weatherwise* is read in East Africa is very gartifying to your editor. The letter from Nairobi, however, raises some fundamental questions about readers of *Weatherwise*. Since this issue completes the tenth volume and tenth year of publication, perhaps it is appropriate to take stock of the present and to plan for the future. Your editor wonders how successful the mission of *Weatherwise* has been in presenting a popular portrayal of American meteorological activities and in chronicling the more important weather events on the North American continent.

Your editor would like guidance from readers as to the content of future issues. He sometimes feels that, like Ulysses, he is navigating dangerously between Scylla and Charybdis, since our reader list covers a wide span of weather interests—from youthful enthusiasts to unenthusiastic professionals. So—, what should we publish? What type of articles do you read with profit, or enjoyment?

May we hear from you? Our address is *Weatherwise*, Box 216, Princeton, New Jersey.

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Front Cover: A winter scene at Monticello near Charlottesville, Virginia, where Thomas Jefferson's daily weather records from 1810 to 1816 formed the basis of his unique study of the Virginia climate. Photo courtesy of the Thomas Jefferson Memorial Foundation.

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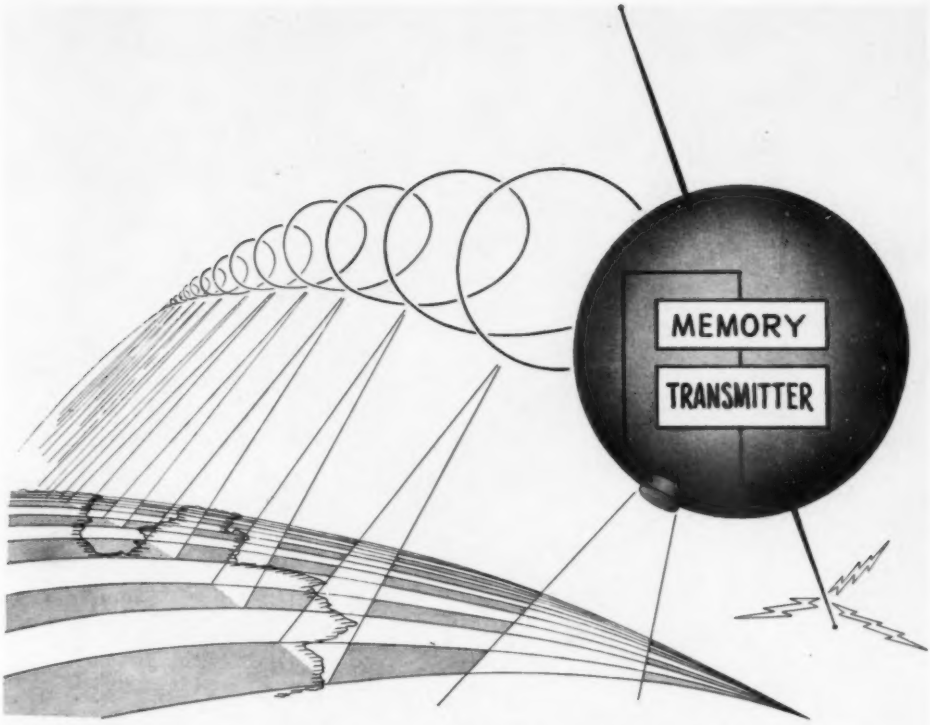


A photocell pointing outward from the spinning satellite scans the earth's surface in a series of lines across the path of the satellite. After transmission to earth, these lines may be reassembled to form an image of the surface and the clouds of the atmosphere.

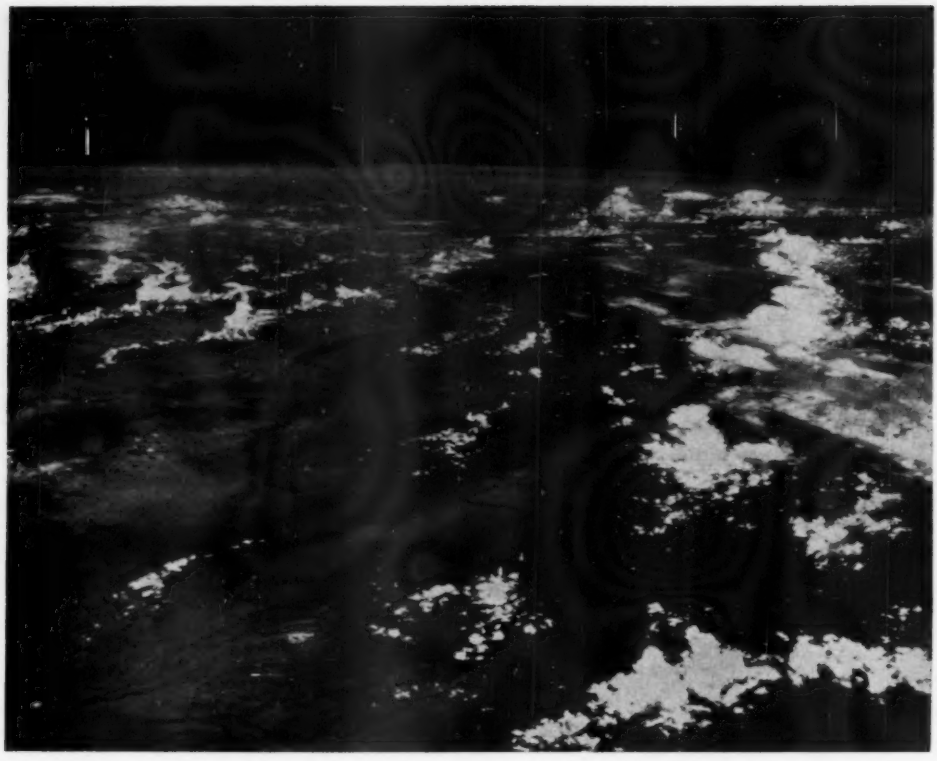
Satellite Television for Meteorology

ARNOLD H. GLASER, *Allied Research Associates, Inc., Boston, Massachusetts*

THE successful launching of the Soviet satellites has abruptly removed the utilization of satellites from the realm of science fiction to that of current events. One of the most attractive promises of the earth satellite is the possibility of viewing the earth as it would be seen from space. While this view would hold no great surprises for the geographer, the meteorologist would for the first time be able to get a global picture of the clouds in the earth's atmosphere.

A picture of the entire earth could be obtained each day. A satellite at moderate altitude—300–500 miles—makes one trip about the earth each 90 minutes or so. During this time the earth turns under the satellite's orbit about 22½ degrees of longitude—about 1,560 miles at the equator. Since the earth and clouds for at least 800 miles on each side of the satellite's track can be seen from the satellite, nearly every point of the earth's surface could come within view of the satellite within a 24-hour period. Sputnik I has an orbit inclined at an angle of 65 degrees to the equator, so that the polar regions, of latitudes greater than 65 degrees, do not pass under the satellite.

It would seem simple to put a miniature

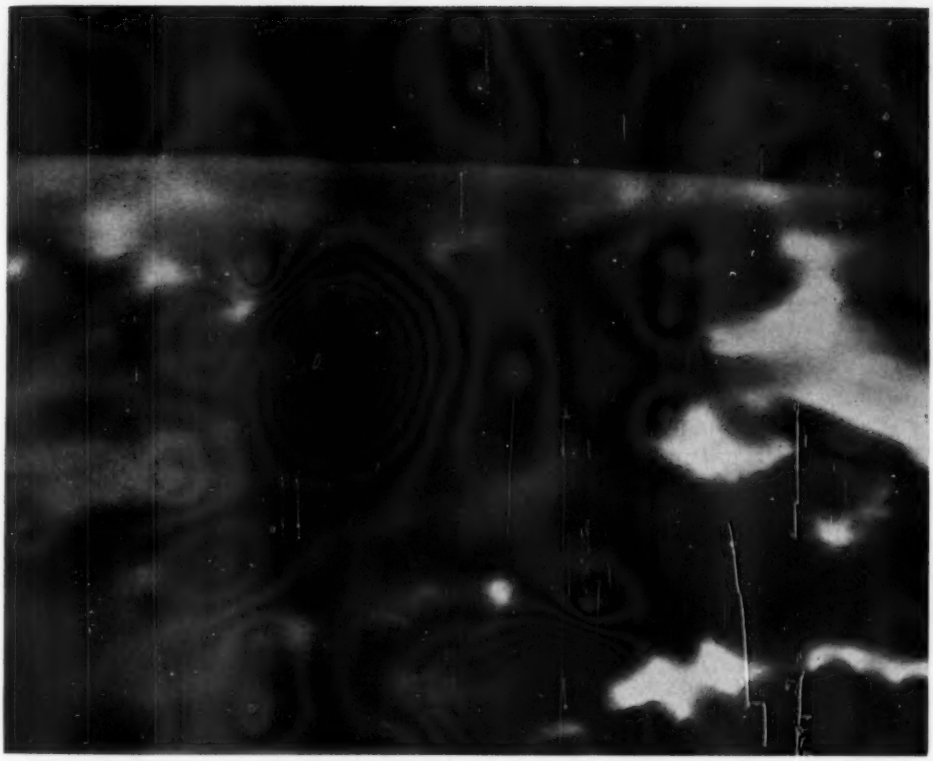


A picture taken from V-2 rocket No. 40 from an altitude of abcut 60 miles above White Sands, New Mexico. The camera is pointed about West. In addition to the obvious cumulus and cumulonimbus clouds, an area of cirrus appears in the upper left and an area of altocumulus on the right. Official U. S. Navy—Johns Hopkins University Applied Physics Laboratory photo.

television camera, perhaps of the "walkie-peepie" variety, on board the satellite. But since the satellite is traveling at a speed of 18,000 miles an hour, the ground and clouds would appear as a hopeless blur as they shoot by underneath. Control of the spinning motion of the satellite would be necessary to preserve the orientation of the camera, as otherwise the observer looking at the television screen on the ground would be presented with a view rapidly alternating between earth, black sky, the sun, and the earth again.

The spin of the satellite, which is probably inevitable, suggests a considerably simpler way of obtaining an image of the surface of the earth than projecting a whole TV station into space. Professor S. F. Singer of the University of Maryland has proposed a very practical scheme: a simple photocell would be arranged to have a very narrow angle of acceptance of light. It would be arranged to point outward from the spinning satellite so that the photocell would scan a strip of the earth at right angles to the track of the satellite. The observer will once more be presented with a view of earth, horizon, sky, and back to earth, but this time all that will be seen is the narrow strip. The next time around, another strip will be scanned, but since the satellite will have advanced some distance in its path, a new area will be surveyed by the photocell. The scanned strips may be put together on the ground to form a picture in much the same fashion that the picture tube of a television set assembles images along fine lines to form a picture.

The faster the satellite spins, the shorter distance its forward motion will carry it be-



The same picture as on the facing page as it would be seen by an image-forming system of about 10 miles resolution. The major cloud systems remain identifiable, although the large cumulonimbus in the upper right is nearly obscured by its own shadow. The light colored ground in the left foreground could easily be confused with cloud; ground of such light color is rarely found except in desert or snow areas. A water background is very dark. Johns Hopkins University Applied Physics Laboratory photo.

tween rotations. Thus, faster spin will result in more closely spaced lines and in improvement of the quality of the image obtained. Of course, this faster spin calls for an equivalent increase in the quality of the optical system and of the electronic system that conveys the image to earth. In principle, at least, there is no limit to the speed at which the satellite can spin, and very little limit to the quality of the simple optical system used. However, there are fundamental limitations to the quality of the picture we can receive at the surface. They apply equally to all scanning systems, whether they be electronic as in television, or mechanical as described here.

As the satellite moves on its orbit about the earth, it spends much of its time out of range of ground receiving stations. But it is just in those areas where the satellite is far from the receiving stations that we would most like information about the state of the earth's atmosphere. Therefore, information must be stored in the satellite until it can be released in a burst when the satellite is within range of the receiving station. Presumably, the signals corresponding to the objects seen on the ground would be stored on magnetic tape during one orbit. Upon receipt of a special signal from the ground station to the satellite, the information stored on the tape would be broadcast rapidly. With its mem-

ory thus wiped clean, the satellite would be ready for another sightseeing trip about the earth.

It is obvious that there is a limit to the amount of information that can be placed on a single small roll of tape of a size that might be carried on board the satellite. A satellite of about the same weight class as Sputnik I might be able to handle a roll of tape of about the size used in ordinary home recorders. It can be shown that such a reel can accommodate enough information to permit a survey of the earth's surface along a 90-minute orbit at a resolution of no more than one mile.

This means that objects smaller than a mile in size could not be separately recognized. Objects only slightly larger than one mile in size could be recognized only in very fuzzy form.

Capacity for information storage on board the satellite is not the only limitation to picture quality. A limitation that is even more serious is caused by the necessarily limited power of the transmitter the satellite carries. A meteorological satellite, to be economically feasible, would probably have to be powered by sun batteries so that it could be useful over many months. This would limit its transmitter power to about that of Sputnik I.

Television owners are quite familiar with differences in picture quality resulting from differences in distance or power of television transmitters. The greater the power or the closer the transmitter, the better is the quality of the picture. Satellite image transmission is affected the same way.

Sputnik I, when its 1-watt transmitter was powered by fresh batteries, managed to be heard by high quality communication receivers over about $\frac{1}{3}$ of its orbit. A signal of sufficient strength to be usable for television transmission is received over perhaps $\frac{1}{8}$ of the orbit. Calculations based on this performance indicate that if Sputnik I transmitted pictures, the definition of the pictures would be poorer than 10 miles.

Any substantial improvement in definition would call for a great increase in transmitter power, with a proportionate increase in weight of transmitter and power supply. It is estimated that a transmitter system capable of transmitting a picture of little better than $\frac{1}{10}$-mile definition would increase the weight of the satellite to well over one ton.

This should lay to rest any fears that Sputnik I or its immediate successors can be readily used as cosmic spies. At a resolution of 10 miles, whole cities are invisible on the earth's surface, let alone what is going on in them. Of course, if the designer of a "spy" satellite arranges in advance for the satellite to focus its attention on a limited area of the earth's surface, better definition is possible.

A 10-mile resolution is obviously of little use for most reconnaissance purposes. The geographer knows most of the surface of the earth with greater accuracy, and few of the activities of man make abrupt changes in 10 × 10 mile squares of the earth's surface. The most prominent features that will be seen are the larger clouds and the snow fields, presented with definition quite adequate to most of the needs of the meteorologist.

The meteorologist seeks an over-all view of the atmosphere without the presence of so much fine detail that neither man nor machine can digest all the information. Such a view permits the easy identification of cyclonic storm systems that have dimensions of several hundreds of miles. It permits fairly ready identification of such disturbances as tropical hurricanes, the squall lines that breed tornadoes (but not the tornadoes themselves), and the fog banks and low hanging clouds that characterize some of the more dismal climates.

While for the first time the meteorologist is offered a global look at the clouds of the atmosphere, it is rash to predict that this will revolutionize forecasting. The view from the satellite does offer advantages that are not available with other systems of data gathering; the quality of the information is just as good over the uninhabited areas of the globe as it is over the eastern United States. It is not immediately clear that any material improvement in forecasting for periods under 24 hours can be expected in most of the continental United States, as ample regular meteorological data is available on a much more frequent schedule to permit the meteorologist to "see" what is coming. But in more isolated areas, and in areas like our Pacific Coast, where the weather arrives from the meteorologically uninhabited ocean, a definite

(*Continued on page 213*)

Mount Vernon, the lovely home of George Washington, where he maintained daily records of the weather when at home from 1767 to 1799. Photo courtesy of The Mount Vernon Ladies' Association.

The Washington and Jefferson Snowstorm

DAVID M. LUDLUM

WASHINGTON will have a major snowstorm of near thirty inches on 27 January 2072! This forecast may seem a bit remote even to some of the most ambitious of long range enthusiasts. If past performances hold true, however, the Nation's Capital should prepare for a snowfall of about thirty inches once every 150 years.

Readers of *Weatherwise* will recall the article on Washington's greatest snowfall, the "Knickerbocker" storm of 27–28 January 1922, appearing in the December 1956 issue. Conrad Mook traced the history of heavy snowfalls in the District of Columbia area back to 1899 and could find no other storm in the 20th century which even closely approached the 28 inches which fell during that 46-hour storm.

The writer has taken up the historical search where Mr. Mook left off. For the years previous to 1899 there are numerous sources of meteorological information about the major storms which have visited the Washington area. Though none of the records is continuous for a long span of years, the various observers make sufficient back reference to previous major storms that one can now be quite confident that no snowstorm of great stature has been overlooked.

When Thomas Jefferson took up residence

in Washington in 1801 at the commencement of his first presidential term, he immediately installed his ever-present thermometer and weather glass at his bedroom window. Since no antecedent meteorological register has been discovered, it seems apparent that Jefferson was the first "chief" of the federal weather bureau. But the third president must give way to a predecessor in office as being the first observer of the general weather in the area, for George Washington at Mt. Vernon had made a habit of recording thermal conditions, wind direction, and state of the sky in a special weather diary. His first continuous weather notes commence in January 1767, and his last entry was penned the day before he died in December 1799.

Washington's weather entries for 26–29 January 1772 make most interesting and significant reading when compared to Mr. Mook's account of meteorological conditions on 27–28 January 1922:

January 26—Raw, cold, and cloudy with the wind tho not much of it Northerly

January 27—A snow which began in the night and was about 5 or 6 inches deep this morning kept constantly at it the whole day with the wind hard and cold from the northward

January 28—The same snow continued all last night and all this day with equal violence the wind being very cold and hard from the Northward drifting snow into banks

January 29—Fine pleasant morning without any wind—but before 11 o'clock it clouded up & threatened snow all the remaining part of the day—being full three feet deep everywhere already

In his regular diary Washington described the day of the 27th as "dreadfully bad" and complained that he was confined to his home on both the 27th and 28th. The following day he relates that "with much difficulty rid as far as the Mill, the snow being up to the breast of a Tall Horse everywhere."

Evidence from other sources has been gathered to indicate that George, indeed, was not telling a lie about the storm or the depth of the snow. The *Maryland Gazette* of Annapolis, the nearest newspaper published to present-day Washington, commented on 30 January 1772:

The winter has in general been very mild until Sunday evening last when it began to snow, which continued without intermission until Tuesday night. Yesterday morning we had again the appearance of fine moderate weather, but in the evening it began to snow very fast which continued all night; tis supposed the depth where not drifted is upwards of three feet, and it is with utmost difficulty people pass from one house to another.

To the south at Williamsburg the deep snow prevented many of the county burgesses from reaching the Virginia colonial capital, so the meeting of the General Assembly had to be postponed. The local *Virginia Gazette* complained about the stoppage of the postal service from the North; it was not until 5 March, five weeks after the storm, that it was able to carry news from a northern source.

Our southernmost check-point for the storm is Bethabara, North Carolina, near present-day Winston-Salem. The Moravian Brethren had established an outpost there in the 1750's and chronicled all the important events, meteorological and otherwise, which befell their frontier community. The Bethabara Diary indicates that rain commenced about 0900 on 26 January 1772 and turned to snow in the evening. Snow fell all the following day, piling up a cover of six inches; toward night clearing set in and it froze. Thus, precipitation commenced in northern North Carolina about twelve hours before it reached Mount Vernon in northern Virginia, a distance of about 250 miles.

That the storm reached westward to the Blue Ridge Mountains of Virginia is well-known to anyone who has visited Monticello and read the historical marker on Jefferson's honeymoon cottage. The owner of that grand weather observation point had been married on New Year's Day of 1772. After a leisurely journey from Charles City during which they stopped with friends along the way, Jefferson and his bride neared their home on the afternoon of the 26th. Most biographers state that Jefferson arrived at Monticello on 25 January. In view of the above meteorological evidence, it appears that he returned from

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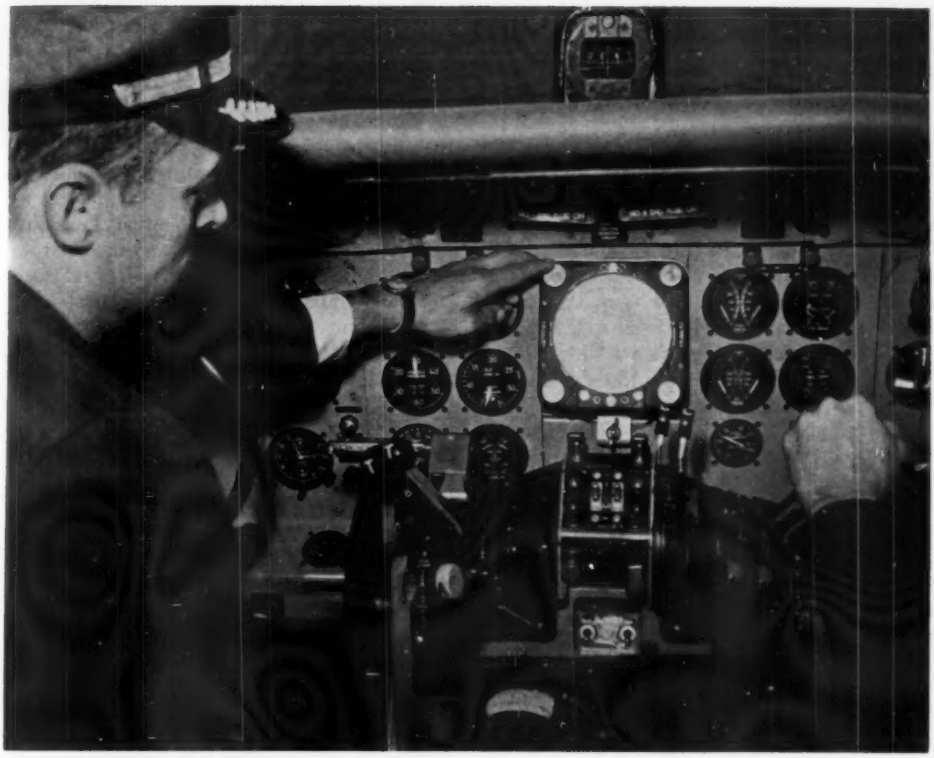


A weather-mapping, C-band radar scope is located in the center of the instrument panel of a DC-7. United Air Lines photo.

Eighteen Months of Storm Avoidance with Airborne Radar

M. E. BALZER, *United Air Lines, Inc.*

WHEN United Air Lines decided to purchase airborne storm avoidance radar, it was based upon a number of considerations. First and foremost, of course, was the fact that radar would increase the safety and comfort of flight during the summer thunderstorm months. Secondly, was the economic justification for an expenditure of over $4 million.

This economic justification depended upon numerous items, some intangible, some tangible and some ancillary benefits. Among the tangible benefits may be listed such things as aircraft damage on account of hail or thunderstorm turbulence. This item alone was estimated to cost in the neighborhood of $400,000 each year. The elimination of long detours to avoid thunderstorm and reduction of air speed to minimize turbulence was estimated to cost approximately $150,000 every year. The elimination of static discharge would also save United Air Lines approximately $25,000 a year. Other tangible bene-

fits would include the elimination of holding delays and reduction of passenger service adjustments.

Among the intangible benefits may be listed such items as increased passenger goodwill and schedule reliability, elimination of cancelled flights due to thunderstorm conditions, and disrupted operations because of excessive delays or landing at off-line points. The ancillary benefits would include improved flight crew morale, reduced insurance premiums, and the possibility that the radar could be used as a navigational aid, indentifying the position of the aircraft with respect to easily identified ground objects.

The purpose of this study is an attempt to see if United Air Lines storm avoidance radar is living up to the expectations of those who recommended the purchase with particular emphasis on the economics of the installation. At this point it might be well to point out that it is impossible to fully evaluate the radar's performance in a completely objective manner because of a number of variables. One would be the difference in thunderstorm frequency and intensity from year to year. Over a period of five to ten years, this condition could probably be averaged out. In other words, the average thunderstorm frequency and intensity for one five-year period over the United Air Lines system would be very close to the average for another five-year period. There are, however, other factors that would still prohibit positive averaging, such as increased exposure to thunderstorms as the mileage flown during the thunderstorm season increases. The increased effect of a single thunderstorm in a high density traffic area would also have a very significant bearing upon the ultimate results. For example, one thunderstorm over Chicago Midway Airport at a peak traffic time of day would cause considerably more disruption of service than the same thunderstorm over the Kansas plains.

In addition to these factors, it is also extremely difficult to obtain significant data on the items under consideration due to the immensity of the sample and the fact that radar will not eliminate all turbulence or weather delays. It is designed to use only in thunderstorm conditions and consequently will prove to be of no benefit in a mountain wave condition or ground fog situation, although these items would still be reflected as turbulence or weather delay in any monthly operations summary.

The sources of the data for this study are United Air Lines performance records such as the flight delay analysis form which is filled out by the flight crews upon completion of a trip. This form indicates the amount of any delay incurred and the reason, such as weather, turbulence, etc. Another source of information is the monthly operating statistics kept by United Air Lines which include such items as number of miles flown on each type of equipment, number of passengers carried, and number and amount of delays. The last informational source used and probably the most significant is a form included with the clearance papers of each trip, designed to check flight crew reaction to airborne radar. This reporting form indicates geographical location of the flight near thunderstorms, the type of avoidance action taken, the general appearance of the thunderstorm area, and any suggestions or comments the flight crew may have regarding the use of radar.

This study is based upon three years of data for the months of April, May, June, July, August, and September which would include almost all of the thunderstorm months on the United Air Lines system. The first item that was examined in detail was the frequency of static discharges. During 1955 in the warm weather months when there was no radar installed on United's fleet, there were 51 static discharges, which is fairly consistent with previous years. The next year, 1956, the fleet was approximately 45 per cent radar equipped and during the same period of time the static discharge cases dropped to 31. In 1957 with 95 per cent of the fleet equipped with storm avoidance radar, there were only 18 cases of static discharge reported, a reduction over the three-year period of 65 per cent. Another item of more than passing significance is the examination of what may be classed as unusual incidents reported by flight crews such as unusual turbulence or landing at an off-line point. In 1955, before the installation was started there were 39 such incidents reported. In 1956, when the fleet installation was approximately one-half complete, the number had dropped to 16 and in 1957 with almost the entire fleet equipped, there were only 8 such incidents. The reduction in this case is close to 80 per cent.

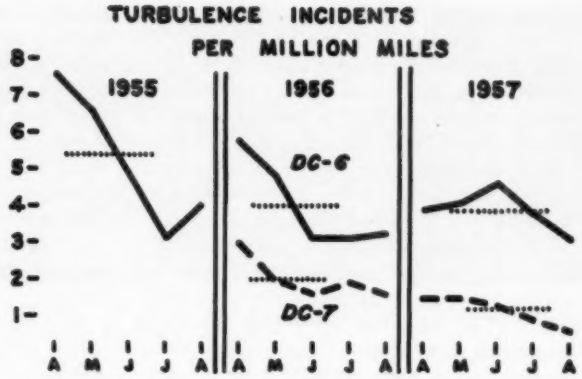


FIG. 1

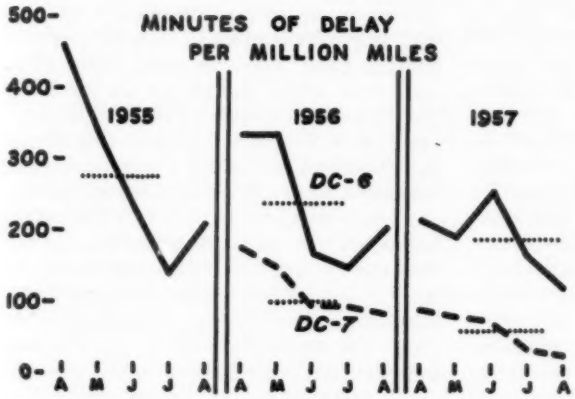


FIG. 2

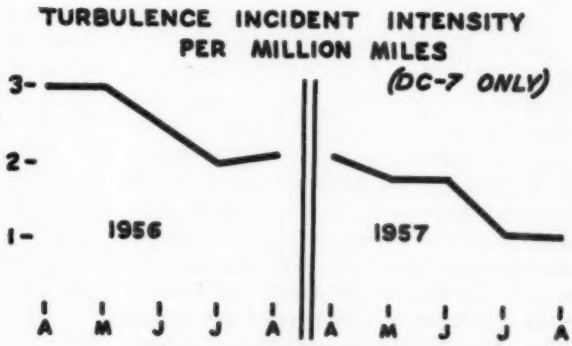


FIG. 3

Next, let us examine the actual number of turbulence incidents reported per million miles flown by United Air Lines during this three-year period. The Hawaii operation is excluded from these figures because of the extremely low incidence of turbulence and thunderstorms on this segment. The four-engine equipment referred to will fly approximately one million miles in between 2½ and 3 days during the summer months. Figure 1 is a graph showing the drop in the number of cases of reported turbulence per million miles flown. The solid line represents the DC-6 fleet which in 1955 had a high of 7.5 turbulence incidents every million miles in April and an average for the entire 1955 period of 5.4 incidents per million miles flown. In 1956, with approximately one fifth of the DC-6 aircraft radar equipped, the high was 5.8, again very early in the year with an average for the year of 4.0. In 1957, with better than four out of every five planes using radar, the high is 4.6 per million miles in June and an average of 3.9 for the year. The high point in June instead of April, as was the case in the preceding two years, would lead a climatologist to suppose the thunderstorm season during 1957 was somewhat different than the previous two years, at least in month of maximum occurrence if not in frequency or intensity. On the same graph the broken line represents the DC-7 fleet and the same down trend is noticeable. During 1956 there was no radar on United Air Lines DC-7's and there was an average of 2.0 incidents of turbulence reported per million miles flown. In 1957 approximately two out of every three DC-7's had radar and the average dropped to 1.2 per million miles.

Figure 2 indicates another interesting graph regarding possible economics of storm avoidance radar. Here is plotted the number of minutes of flight delay due to turbulence which would include time involved in detours at reduced throttle, etc. per million miles flown. Again the heavy line is for the DC-6 equipment and in 1955 with no radar there were 276 minutes of flight delays per million miles flown. In 1956 when 20 per cent of this fleet was radar equipped, the average was down to 237 minutes per million miles and in 1957 with approximately 80 per cent of the DC-6 fleet equipped, the average dropped to 189 minutes per million miles flown. It is interesting to note again the peak in June of 1957 which corresponds to the June peak in figure 1 and indicates that there was a real difference in the thunderstorm pattern during 1957. On the same chart the DC-7's before radar was installed averaged 101 minutes turbulence delay per million miles and in 1957, with the installation approximately 65 per cent complete, the average dropped to 61 minutes per million miles.

By putting these figures together we can arrive at figure 3 which is perhaps the most significant of all. Figure 1 indicated a down trend in the number of incidents per million miles, figure 2 indicated a down trend in the minutes of turbulence delay per million miles, and in figure 3 we see a definite trend in the number of minutes of turbulence per incident per million miles. This, of course, is nothing more than the total time of the turbulence delays divided by the number of incidents and is only computed for the DC-7 fleet. In 1956 with no radar on this aircraft, there is a high in April of 3 minutes per incident per million miles with the trend down as the season progresses to a low of 2.1 minutes in August. In 1957 with radar now on two-thirds of the DC-7 fleet, the high is again in April of 2.1 minutes continuing down to 1.05 minutes per incident per million miles in August. The significant point here is, of course, that the high in 1957, using storm avoidance radar, is the same as the low the previous year before radar was installed.

The last and probably the most significant item in this study is the radar reporting form. Since radar first appeared on the United fleet, these reports have been filled out and forwarded by the flight crews, and we now have on hand over 1,000 reports. Inasmuch as this is a statistical study, we will break these reports into percentages. Approximately 90 per cent indicate a definitely favorable reaction to airborne radar. About 7 per cent are noncommittal, generally because radar was not needed on that particular flight or because an ARTC clearance along the desired detour path was impossible to obtain. The remaining 3 per cent would be classed as unfavorable. These adverse reactions are usually

(Continued on page 213)

A view of Whiteface Mountain, a 4872-foot peak in the Adirondacks of New York State. Photo by Whiteface Mountain Authority.

The Museum of the Atmosphere

VINCENT J. SCHAEFER, *Director of Research,*
The Munitalp Foundation, Inc.

THERE are few persons who are not interested in the weather—but still fewer who have some understanding of the complex happenings in the atmosphere which combine to cause its variabilities from day to day.

Many attempts to explain weather have been made, using methods ranging from classroom lectures to educational movies, television programs, illustrated guide books, diagrams, and working models. All have their place, but few achieve more than a limited success.

I have proposed a new approach to the problem with its main objective being the presentation in simple, but scientifically accurate, exhibits, diagrams, dioramas, working instruments, and models—a dynamic presentation of the weather effects happening outside the door of the building. This assemblage of exhibits will become the Museum of the Atmosphere.

The basic core of the exhibits is a large assemblage of recording weather instruments. The museum, which is now under initial development on the summit of Whiteface Mountain in the Adirondacks of New York State, is sponsored by the Whiteface Mountain Authority, a state agency. Our Foundation is actively engaged in supplying the technical guidance to the project.

At the present time most of the recording instruments have been installed and quite a number are being operated to obtain representative samples for use in preparing realistic exhibits.

Since Whiteface Mountain is the only high mountain in New York State having a good auto road to its summit, the mountain is the objective of many thousands of tourists throughout the spring, summer, and fall. Now that a multimillion dollar ski development is being completed in a snow bowl directly downwind from the summit, we anticipate the Museum will serve also as a weather observatory and eventually may operate throughout the year.

One of the most useful features of the Museum will be that no matter whether the mountain is covered with clouds or not, a visit to the summit will be an interesting and memorable experience. In fact, a visit during a storm will present attractions not present during clear weather. Many of the weather instruments should be of special interest under such conditions, especially those measuring precipitation, wind, electricity, cloud water, radiation, visibility, and temperature. Since the instruments are all mounted in close proximity to each other, the moving needles will often show relationships illustrating the interdependencies of different weather parameters.

Whiteface Mountain was used as a site for

a weather observatory from the late 1930's into the early phases of World War II when students and professors of Rensselaer Polytechnic Institute of Troy, N. Y. conducted weather observations and research studies. The writer assisted in the first icing studies of helicopter rotor blades on the mountain, conducted by personnel of the U. S. Air Force propeller laboratory of Wright Field. These studies were made during the winter of 1944–45 and emphasized the seriousness of icing conditions to the safety of such aircraft.

Some of the current instrumentation and plans for developing the Museum of the Atmosphere are as follows:

Moisture

The moisture pattern of a mountain summit is a fascinating study. A variety of recording instruments ranging from a tipping bucket rain recorder to a cloud meter are planned. We intend to illustrate the cloud catch of trees, grasses, bushes, and other objects when non-precipitating clouds swirl over the summit. Several dewpoint recordings will be made, including one in the tunnel which leads into the heart of the mountain.

By making plastic replicas of rime formations, we can illustrate the collection efficiency of different shaped objects; and by making replicas of the crystals falling in snowstorms, we will illustrate the variations which occur in storms of different types.

Samples of precipitation from all types of storms will be concentrated and photomicrographs will be made of the residue, to show the various types of organic and inorganic impurities contained in clouds and precipitation.

The liquid water content, the average cloud particle size, and size distribution will be measured with cloud meters of the type developed at Mt. Washington when we were studying cloud structure.

Time lapse motion pictures of the various types of clouds which occur at the mountain will be shown by automatic movie projector. If the summit is in cloud, the type of cloud on the mountain at the time will be depicted.

Temperature

A multichannel recorder will be used to show the variations in temperature which occur on a mountain summit. In addition to the sensing element located in a standard instrument shelter, we plan to measure the temperature at other locations. One of the units will be imbedded in the primary granite of the summit far down in the side of the elevator shaft which pierces the center of the mountain. This unit will probably show the least fluctuation of all, but the long range trends may be interesting. Another will be imbedded in the rock on the summit but within a few centimeters of the surface. A fourth will rest on the surface of the rock but underneath the thick bed of tundra-like moss in the above timber line zone. A fifth will be placed only a centimeter below the surface to show the diurnal fluctuations which produce the thermal gradients in the soil. A sixth will be located in free air and unsheltered. This will illustrate the great variations which occur due to heat absorption and radiation. A seventh will be placed in an instrument shelter on top of the tower and will illustrate the effect of elevation and wind exposure to temperature. An eighth will illustrate the loss of heat which occurs on cold, clear nights when radiative cooling reaches a maximum.

Pressure

A standard mercurial barometer, a recording microbarograph, a barovariograph, and a pressure altimeter will be used to illustrate the effect of pressure, changes of pressure, and effects of high winds on meteorological situations at the mountain. Diagrams will illustrate the significance of these factors in the various weather patterns of the area.

Optical Effects

There are few places in the world where a greater variety of optical effects can be found than on a mountain summit. Models will be utilized to illustrate such phenomena as the glory, the rainbow, the sun pillar, the 22°, 46° and other ice crystal halos, the under sun, sun dogs, light scattering as related to particle size, the reason for blue, yellow, and red suns, the cause of haze, the corona and similar effects caused by liquid and solid particles floating in the air.

Instruments will measure incoming and outgoing radiation, the reflection from upper clouds, and the light scattered by haze and local clouds.

Electrical Effects

A steep mountain summit like Whiteface causes spectacular electrical effects during both clear and stormy weather. The sound of precipitation static, the appearance, effects and cause of St. Elmo's Fire, and the incidence of cosmic radiation will be illustrated with sound tape, photographs, and models. Instruments will record the earth's field, air conductivity, corona current, and lightning effects.

Aerosols and Gases of the Atmosphere

Models will illustrate the relative sizes and density of airborne particles found in the vicinity of the mountain, including condensation and ice nuclei, pollen, industrial, and natural smokes. In order to relate these floating particles in proper perspective, scale models will be used to illustrate their concentration as compared to the gases and vapors which are the essential part of the atmosphere. To complete the picture, the liquid water content of various types of clouds and the relative sizes and types of liquid and frozen precipitation will round out the exhibit.

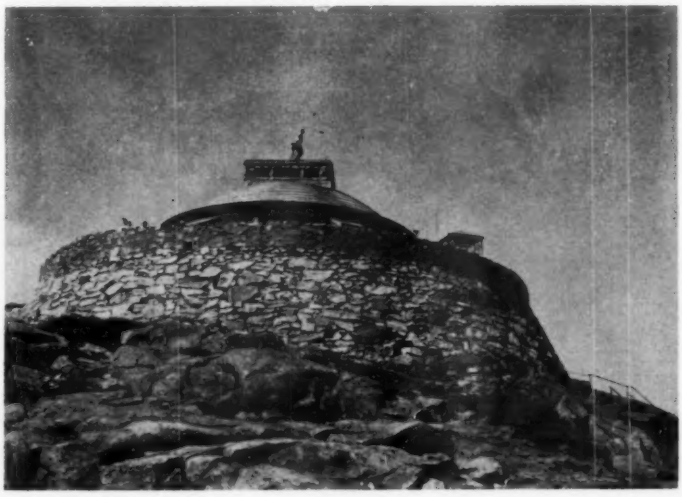
Climatic Regimes of the Adirondacks

A group of exhibits will relate the summit of the mountain to the global world and its satellites and illustrate these dimensions by using relative scales on three-dimensional models. The thickness of the atmosphere extending upward to about a thousand miles above the earth will show the various layers as now understood, the orbits of the IGY satellites, and related phenomena of current interest.

By using cross sections of timber line trees, the accumulation of soil from weathered rock and the cross sections of humus layers on the mountain, including its pollen profile, a picture of the post-glacial climate of Whiteface Mountain will be depicted. Block diagrams will also relate the various elevations of the mountain to their sea level counterparts in the tundra and moss horizons of the subpolar regions of the north.

Working Models

Working models of the Schaefer type of cold chamber, diffusion cloud chamber and cloud model box, a diffusion cloud chamber to illustrate cosmic rays, a standard cloud chamber to illustrate the level of atmospheric condensation nuclei, the Rayleigh electric fountain, a tornado model and similar methods for illustrating atmospheric reactions are being planned. The installation of these and related exhibits will depend on the enlargement of the present summit building.



The summit building atop the peak where the Museum of the Atmosphere is located. Photo by Whiteface Mountain Authority.

Wind

Standard wind velocity and direction recorders are installed. Special heated vaned pitot tubes will be required for winter use due to the excessive winds and severe icing which occurs from November till April on Whiteface Mountain. A draft recorder such as has been used successfully at Mt. Washington will be used when winter measurements are needed.

The behavior of a mountain in causing mountain and valley winds, the cause of down drafts, wave clouds, rotor clouds, and similar phenomena will be illustrated by diagrams, photos, and time lapse movies.

If plans develop as scheduled, it is hoped that the museum will be completed by 1960. Suggestions for making the exhibits interesting and worthwhile would be welcomed by us, especially with regard to push-button-type working models. These must be simple, understandable, and of significant import in relation to atmospheric phenomena.

It is hoped that the experiences gained at the Whiteface Mountain Museum can be used to establish similar institutions at other favorable locations. If successful, we expect the displays will arouse an active interest in meteorology and related atmospheric sciences among some of the young people who visit it. If this occurs, the effort will be worthwhile.

A view of the temporary instrument panel with recorders for outside wind, temperature, pressure, rainfall, electricity, and radiation. Photo by Falconer & Maynard.

Importance and Need of Degree-Day Forecasting for the Petroleum Industry

W. J. SWEENEY, *Vice President,*
Esso Research and Engineering Company, New York

FORECASTS of product requirements have an important influence on every phase of petroleum industry operation. While much work has been done to improve product requirement estimates, certain factors still remain which, at the present time, cannot be predicted with reasonable accuracy. The unpredictable variations in these factors are responsible for the major supply problems of the industry.

One of the most important of these unpredictable factors is weather. Many operations within the petroleum industry, including exploration, producing, marine, pipeline, refining, etc., are seriously affected by weather. Notably important because it indirectly affects all petroleum operations is the effect of weather on petroleum products used each year for residential heating. The demand for some 450 million barrels of these products is directly related to the severity of the heating season. While many of the past winters have been moderate throughout most of the country, extremely warm or extremely cold seasons do occur, and the industry has the responsibility of supplying its customers, regardless of the weather.

Winter demands for heating oil are met from inventory that has been built up during the summer in addition to the production during the heating season. In past years, gasoline for the summer was the planning problem. In recent years, particularly in the northern and more populous areas, the major planning problem has been heating oils or middle distillates. In future years, with larger diesel and jet fuel demands, as well as with increasing heating oil demand, the problem of planning heating oil needs will become more acute.

Figure 1 indicates the year-round planning required to meet normal heating oil demand.

Inventory is at a minimum in April. By the end of April, usually the refinery output of middle distillates will exceed the demands and the inventory in storage starts to build up. During the summer months, the sales of middle distillates are accounted for only by nonheating purposes and by secondary storage. During this period, the inventory is built up to take care of the anticipated demands of the coming winter. Maximum inventory is in tankage in November; and for the period November through March, sales are met from inventory as well as from current production.

The refiner has several reasons to keep production reasonably constant during the year. First, it is most economical to maintain a rather uniform production rate throughout

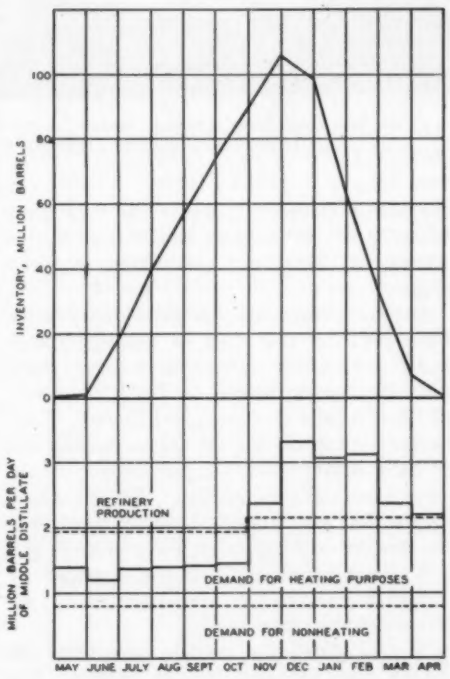


FIG. 1. Year-round planning required to meet normal heating oil demand.

The Esso Gettysburg, a modern tanker 715 feet in length and of 37,800 deadweight tons, can transport 318,000 barrels of oil at a speed of 20 knots. Photo by Esso Shipping Company.

the year. Secondly, this provides more flexibility, either to increase production in cold winters or to reduce production in warm seasons.

For some time, the petroleum industry has been aware of the effect of weather, specifically temperature, measured in degree days, over the heating season on the consumption of burning oils in the United States. Total degree days in the heating season are the sum of daily degree days, i.e., the number of degrees below 65 for each day. These seasonal degree days give a fairly accurate measure of the amount of heating oil and range oil that will be consumed for heating purposes.

Figure 2 shows the New York, N. Y., degree day data since 1870.

In this chart, the verticle bars show the degree days for each heating season. The heavy line shows the long-term trend towards warmer weather, indicating that the New York average seasonal degree days have decreased from about 5,650 degree days in 1870 to under 5,000 at present.

While there is a trend towards warmer winters, individual heating seasons show wide fluctuations from year to year. For example, during the past 25 years, the coldest heating season in New York was 1939–40, with the average temperature in degree days 10.1 per cent colder than the average for the past 50 years. The warmest season was 1948–49 with the average temperature 18.7 per cent warmer than the 50-year average. Therefore, in the past 50 years, the degree day totals for individual heating seasons in New York have varied over a range of 28.8 per cent of the 50-year average.

The range of variation in degree days between coldest and warmest seasons is roughly the same for the United States as it is for New York City. This means that the demand for

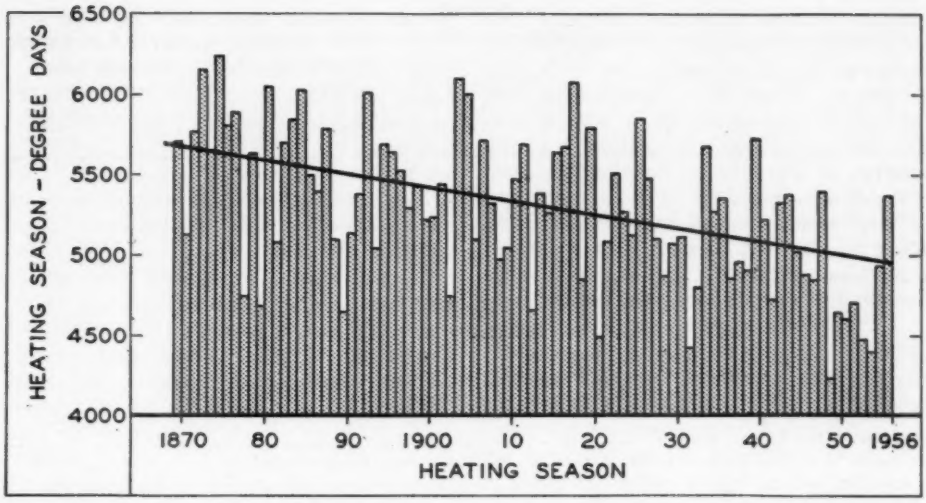


FIG. 2. Trend of warmer weather—New York City degree days, 1870–1956.

middle distillates in the coldest seasons might exceed that in the warmest by as much as 125 million barrels. This is equivalent to a variation of 700 thousand barrels per day in industry demand over the 6 months heating season period. These figures may be regarded as rough measures of the range within which demand may fluctuate unpredictably due to weather.

The requirements of inventory in the petroleum industry needed to meet the unusually cold or warm season are shown in figure 3.

The additional sales of heating oil during a cold winter must be met by additional inventory as well as by increased production during the heating season. The inventory on hand in September must be such that in a cold winter we will not run out of oil during the heating season. Therefore, for normal weather, considerable oil will be in storage at the end of the winter. The maximum tankage must provide for additional inventory that is built up in October and November when the demand is less than expected due to unusually warm fall weather. Tankage space above that required for normal weather must be available to take care of this possible inventory buildup.

As a practical situation, we have some limit on the available tankage above the normal inventory peak in November and a limit on the available oil in storage below the normal dip in April. The "normal" inventory level for the month is always the safest level. With proper planning, the "normal" level allows for the possibility of either very cold or very warm months to follow. In other words, we are trying to walk a "tightrope." If inventory overflows capacity before November, we are in trouble; likewise, if it is too high in April, we will have extra expense during the summer, cutting production to abnormally low levels by recracking, etc. If inventory runs too low through November, or dips too much below normal level at any time during

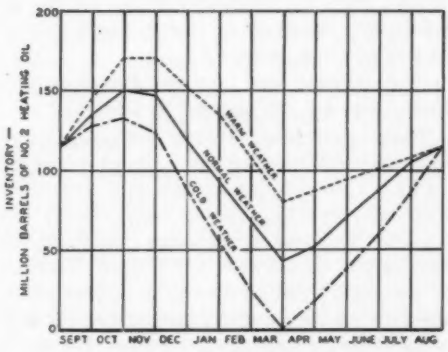


FIG. 3. Inventory of heating oil.

TABLE 1

	Required storage		Average inventory	
	Million barrels	Per cent of yearly demand	Million barrels	Per cent of yearly demand
Case 1				
No forecast used—				
No adjustment of production rate during the season	185	41.0	108	24.0
Case 2				
No forecast used—				
Monthly adjustment of production rate after cold or warm weather occurs	167	37.0	98	21.7
Case 3				
Use of 50 per cent improved 3-month forecast—				
Monthly adjustment of production rate, based on forecast and previous weather	140	31.0	78	17.3

the season, we are in for a shortage problem if the ensuing months are cold.

Without adequate forecasts, the month-to-month readjustment in refinery runs can be made only on the basis of weather that has occurred. Seasonal forecasts of degree days could be used to assist the periodic readjustment of refinery runs during the season. By continually planning our readjustments in advance of the weather, using both the improved forecast and the necessary adjustments for the cold or warm months that have occurred, we can keep our inventories at safer levels on the average than with adjustments based only on the weather which has happened. The schedule of production would not rely on a single preseason forecast. Rather, we would use each series of forecasts obtained during the season and presumably could correct by afterplanning and by use of subsequent forecasts for errors made in one or two of these forecasts.

The tankage and average inventory for three cases are summarized in table 1.

Each case involves exactly the same risk of incurring additional expense to meet demands. In Case 1, no forecast is used, and no adjustment of production rate is made during the season. This requires tankage availability to take care of 41 per cent of the yearly demand of heating oil and an average inventory of 24 per cent of the yearly requirements. Case 2 is based on no forecast, but does include a monthly adjustment of production rate after warm or cold winter weather occurs. In this case, 37 per cent of the yearly demand is required as available tankage, and the average inventory is 21.7 per cent of the yearly requirement. In Case 3, an improved 3-month forecast is used and monthly adjustments of production rate are scheduled, based on forecasts and on the previous weather. In this case, tankage equaling 31 per cent of the yearly demand must be available, and the inventory is 17.3 per cent of the yearly demand.

The comparison of Case 1 and Case 2 has been shown to indicate the advantage of monthly planning even without the use of temperature forecasts. The comparison between Case 2 and Case 3 indicates the value of the improved forecast. Using these figures, it is estimated that the improved forecast might be worth the values shown in table 2.

The figures in table 2 show a reduction in tankage costs of 40 million dollars and a saving in capital tied up in inventory of 60 mil-

TABLE 2

REDUCTION IN TANKAGE AND INVENTORY WITH IMPROVED FORECAST

Tankage (6.0 per cent of yearly demand) 27 million barrels at $1.50 per barrel	$ 40,500,000
Inventory (4.4 per cent of yearly demand) 20 million barrels at $3.00 per barrel.	60,000,000
Total	$100,500,000

lion dollars, giving a total saving for the industry of 100 million dollars.

It is felt that this estimate of the value of improved forecasts, while very rough, is also very conservative, because it is based only on tankage savings. Based on actual operations as of today, many high cost operations are required to meet unseasonable demands. A good forecast would result in lower manufacturing costs, and on this basis the potential saving would be very much larger.

The petroleum industry is committed to a basic obligation that it must supply the consuming public with its demands for heating oil. The industry assumes this obligation whether or not the heating season is unusually cold or warm.

Theoretically, the industry could provide for the demand for heating oil without large inventory if it built sufficient refining capacity to make all of the requirements during the heating season. If this were done, large amounts of standby refinery capacity would be needed to provide for the heating oil demands as they occurred. In order to do this, over 1½ million barrels per day additional refining capacity would have to be constructed at the cost of over one billion dollars. This equipment would be used on a part-time basis and would be costly to the industry and costly to the public.

Rather than have this large amount of standby capacity, the industry has found instead that it is better to build up heating oil inventory during the summer as a cushion for the large winter demands. In order to meet the requirements of unusual weather at the minimum cost to the industry and the minimum price to the consumer, great efforts are made within the industry to achieve the proper balance between month-to-month changes in refinery operations and available heating oil in inventory for each month throughout the year.

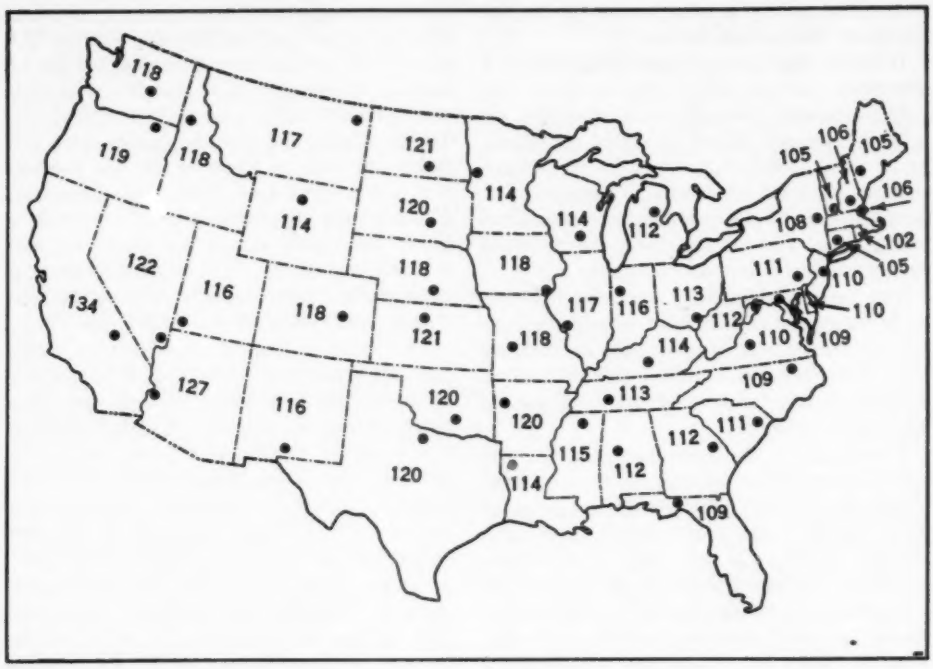
The use of weather forecasting to supplement present methods of scheduling by the petroleum industry must provide assurance that the industry will be able to supply the heating oil customers with their requirements. One objective must be that no greater risk is taken of running out of heating oil when plans are based on a long-range forecast than there is now. Our studies have shown that even a partially successful forecast, continually corrected by afterplanning during the season, can reduce the risk of running out of heating oil during a cold season. A reasonable forecast could considerably reduce the danger of finishing a winter season with full tanks and with no place to put the production which must take place in the summer. Alternatively, the forecast could be used to reduce costs while taking the same risks that are necessary today. In the final analysis, a good weather forecast would probably be used to accomplish both of these objectives.

The value in heating oil scheduling is, in fact, only one facet of the wide interests and needs of the petroleum industry for long-range weather forecasting. Weather forecasting is vitally needed in marine, producing, pipeline, and other phases of the industry's activities. In all of these fields, the forecasts can be used to supply the needs of the customer with greater assurance and lower cost.

While weather is a subject of great importance in the public eye, and there is a great deal written on the subject, it is interesting to observe that the cost of the total actual research being carried out in the field of long-range weather forecasting is perhaps in the order of two-tenths of one per cent of that carried out by the petroleum industry on petroleum refining research. Further, the proportion of this relatively limited overall work on long-range weather which is being carried out on the kind of temperature forecasting of interest to the petroleum industry is sufficiently small that a project in the order of $25,000 to $50,000 per year would constitute a major project of its kind in the field and would be sure to be recognized as such. It is intriguing that a project so small by the petroleum industry's standards might have some chance of success.

Some of the accomplishments expected of API sponsored long-range weather projects are: 1. The project will present to the industry the best information on the average temperatures they can expect in various localities together with the deviations from this average temperature that might be expected at a given probability level. While some of this information could be obtained from the Weather

(*Continued on page 214*)



Climatological Extremes—3

L. H. Seamon and G. S. Bartlett, *Office of Climatology, U. S. Weather Bureau, Washington, D. C.*

HIGHEST TEMPERATURES IN THE UNITED STATES BY MONTHS

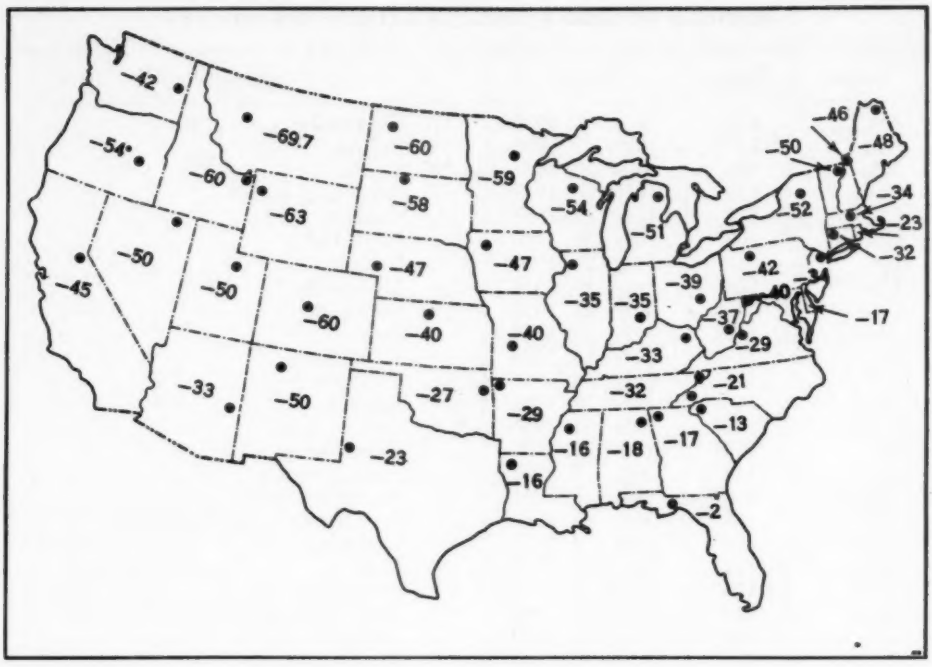
Month	Temp. F.	Year	Day	State	Place
Jan.	98*	1936	17	Texas	Laredo
Feb.	105	1902	6	Calif.	Palm Springs
Mar.	108	1954	31	Texas	Rio Grande City
Apr.	118	1898	25	Calif.	Volcano Springs
May	124*	1896	21	Calif.	Salton
June	129*	1902	23	Calif.	Volcano Springs
July	134	1913	10	Calif.	Greenland Ranch
Aug.	130	1885	17	Calif.	Amos
Sept.	126	1950	2	Calif.	Mecca
Oct.	116*	1917	5	Ariz.	Sentinel
Nov.	105*	1906	12	Calif.	Craftonville
Dec.	100	1938	8	Calif.	La Mesa

* More than one occurrence; most recent date given.

RECORD HIGHEST TEMPERATURES BY STATES

State	Temp.	Date	Station
Ala.	112	Sept. 5, 1925	Centerville
Ariz.	127*	July 7, 1905	Parker
Ark.	120	Aug. 10, 1936	Ozark
Calif.	134	July 10, 1913	Greenland Ranch
Colo.	118	July 11, 1888	Bennett
Conn.	105	July 22, 1926	Waterbury
Del.	110	July 21, 1930	Millsboro
Fla.	109	June 29, 1931	Monticello
Ga.	112	July 24, 1952	Louisville
Idaho	118	July 28, 1934	Orofino
Ill.	117	July 14, 1954	E. St. Louis
Ind.	116	July 14, 1936	Collegeville
Iowa	118	July 20, 1934	Keokuk
Kans.	121*	July 24, 1936	Alton (near)
Ky.	114	July 28, 1930	Greensburg
La.	114	Aug. 10, 1936	Plain Dealing
Maine	105*	July 10, 1911	North Bridgton
Md.	109*	July 10, 1936	Cumberland and Frederick
Mass.	106*	July 4, 1911	Lawrence
Mich.	112	July 13, 1936	Mio
Minn.	114*	July 6, 1936	Moorhead
Miss.	115	July 29, 1930	Holly Springs
Mo.	118*	July 14, 1954	Warsaw
Mont.	117*	July 5, 1937	Medicine Lake
Nebr.	118*	July 24, 1936	Minden
Nev.	122*	June 23, 1954	Overton
N. H.	106	July 4, 1911	Nashua
N. J.	110	July 10, 1936	Runyon
N. Mex.	116*	July 14, 1934	Orogrande
N. Y.	108	July 22, 1926	Troy
N. C.	109*	Sept. 7, 1954	Weldon
N. Dak.	121	July 6, 1936	Steele
Ohio	113*	July 21, 1934	Gallipolis (near)
Okla.	120*	July 26, 1943	Tishomingo
Oreg.	119*	Aug. 10, 1898	Pendleton
Pa.	111*	July 10, 1936	Phoenixville
R. I.	102*	July 30, 1949	Greenville
S. C.	111*	June 28, 1954	Camden
S. D.	120	July 5, 1936	Gannvalley
Tenn.	113*	Aug. 9, 1930	Perryville
Tex.	120	Aug. 12, 1936	Seymour
Utah	116	June 28, 1892	Saint George
Vt.	105	July 4, 1911	Vernon
Va.	110*	July 15, 1954	Balcony Falls (P.O.: Glasgow)
Wash.	118	July 24, 1928	Wahluke
W. Va.	112*	July 10, 1936	Martinsburg
Wis.	114	July 13, 1936	Wisconsin Dells
Wyo.	114	July 12, 1900	Basin
Alaska	100	June 27, 1915	Fort Yukon
D. C.	106*	July 20, 1930	Washington
T. H.	100	April 27, 1931	Pahala (elevation 850 feet)

* More than one occurrence; most recent date given.



Climatological Extremes—3

LOWEST TEMPERATURES IN THE UNITED STATES BY MONTHS

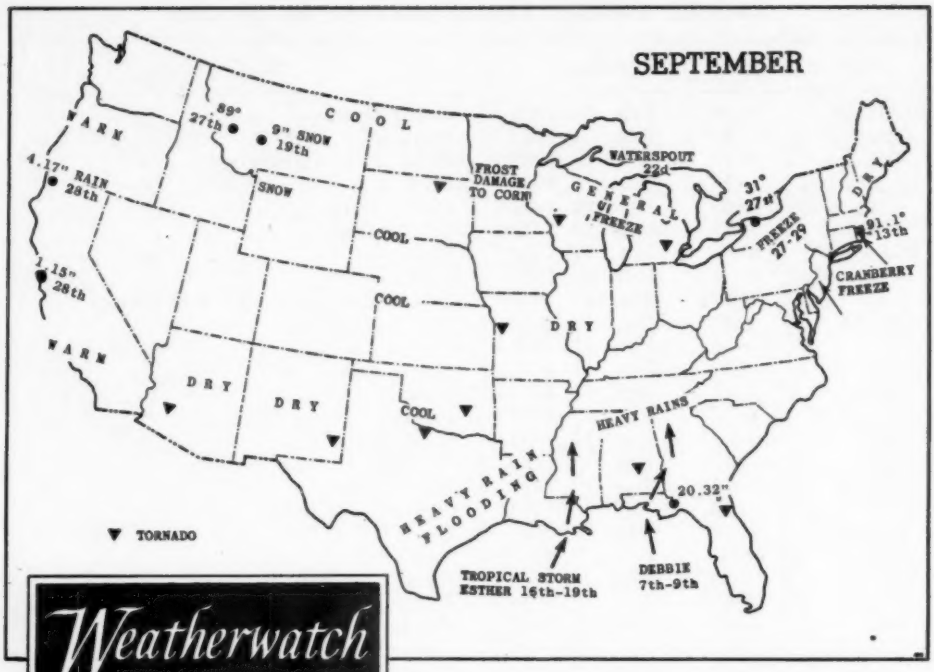
Month	Temp. F.	Year	Day	State	Place
Jan.	−69.7	1954	20	Mont.	Rogers Pass
Feb.	−66	1933	9	Mont.	Riverside R.S.
Mar.	−50	1906	17	Wyo.	Snake River
Apr.	−36	1945	5	N. Mex.	Eagle Nest
May	−10	1896	14	Colo.	Climax
June	2	1907	13	Calif.	Tamarack
July	10*	1911	21	Wyo.	Painter
Aug.	5*	1910	25	Mont.	Bowen
Sept.	−9	1926	24	Mont.	Riverside R.S.
Oct.	−33	1917	29	Wyo.	Soda Butte
Nov.	−45	1896	30	Minn.	Pokegama Dam
Dec.	−59	1924	19	Mont.	Riverside R.S.

* More than one occurrence; most recent date given.

RECORD LOWEST TEMPERATURES BY STATES

State	Temp.	Date	Station
Ala.	−18	Feb. 14, 1905	Valley Head
Ariz.	−33*	Jan. 4, 1949	Maverick
Ark.	−29	Feb. 13, 1905	Pond (P.O.: Gravette)
Calif.	−45	Jan. 20, 1937	Boca
Colo.	−60	Feb. 1, 1951	Taylor Park
Conn.	−32	Feb. 16, 1943	Falls Village
Del.	−17	Jan. 17, 1893	Millsboro
Fla.	− 2	Feb. 13, 1899	Tallahassee
Ga.	−17	Jan. 27, 1940	CCC Camp F-16 (near LaFayette)
Idaho	−60	Jan. 18, 1943	Island Park Dam
Ill.	−35	Jan. 22, 1930	Mount Carroll
Ind.	−35	Feb. 2, 1951	Greensburg
Iowa	−47	Jan. 12, 1912	Washta
Kans.	−40	Feb. 13, 1905	Lebanon (P.O.: Bellaire)
Ky.	−33	Feb. 11, 1899	Sandyhook
La.	−16	Feb. 13, 1899	Minden
Maine	−48	Jan. 19, 1925	Van Buren
Md.	−40	Jan. 13, 1912	Oakland
Mass.	−34	Jan. 18, 1957	Birch Hill Dam
Mich.	−51	Feb. 9, 1934	Vanderbilt
Minn.	−59*	Feb. 16, 1903	Pokegama Dam
Miss.	−16*	Feb. 2, 1951	Batesville
Mo.	−40	Feb. 13, 1905	Warsaw
Mont.	69.7	Jan. 20, 1954	Rogers Pass
Nebr.	−47	Feb. 12, 1899	Camp Clarke
Nev.	−50	Jan. 8, 1937	San Jacinto
N. H.	−46	Jan. 28, 1925	Pittsburg
N. J.	−34	Jan. 5, 1904	River Vale
N. Mex.	−50	Feb. 1, 1951	Gavilan
N. Y.	−52	Feb. 9, 1934	Stillwater Reservoir
N. C.	−21*	Nov. 30, 1929	Mt. Mitchell
N. Dak.	−60	Feb. 15, 1936	Parshall
Ohio	−39	Feb. 10, 1899	Milligan
Okla.	−27*	Jan. 18, 1930	Watts
Oreg.	−54*	Feb. 10, 1933	Seneca
Pa.	−42	Jan. 5, 1904	Smethport
R. I.	−23	Jan. 11, 1942	Kingston
S. C.	−13	Jan. 26, 1940	Longcreek (near) (P.O.: Mountain Rest)
S. Dak.	−58	Feb. 17, 1936	McIntosh
Tenn.	−32	Dec. 30, 1917	Mountain City
Tex.	−23*	Feb. 8, 1933	Seminole
Utah	−50*	Jan. 5, 1913	Strawberry Tunnel, east portal
Vt.	−50	Dec. 30, 1933	Bloomfield
Va.	−29	Feb. 10, 1899	Monterey
Wash.	−42	Jan. 20, 1937	Deer Park (near)
W. Va.	−37	Dec. 30, 1917	Lewisburg
Wis.	−54	Jan. 24, 1922	Danbury
Wyo.	−63	Feb. 9, 1933	Moran
Alaska	−76	Jan. −, 1886	Tanana
D. C.	−15	Feb. 11, 1899	Washington
T. H.	18	Feb. 9, 1941	Haleakala (elev. 9,750 feet)

* More than one occurrence; most recent date given.



A Southerly Jet Stream Marks the Early Fall

DAVID M. LUDLUM, *Editor*

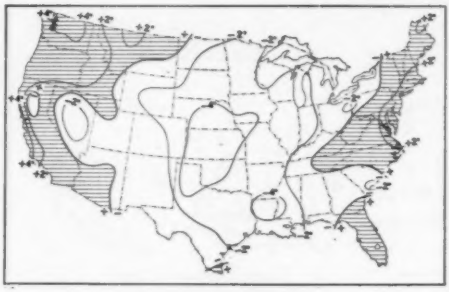
The summer-type circulation which had held steady during July and August underwent a distinct change early in September. By the 6th the large semi-tropical anticyclone, found over Texas, Oklahoma, and Louisiana most of the summer, retreated southwestward into Mexico, and the large ridge of high pressure extending northward over the Great Plains disappeared. The ridge was replaced by a full length trough, stretching from the Arctic to the Gulf of Mexico. This trough, which covered the entire Mississippi Valley, became the main feature of the upper-air circulation maps until the last days of the month.

With a western ridge-central trough-eastern ridge system established, air flow across the United States was classified as low index. In fact, September continued the long string of months in 1957 which have had below normal westerly flow. The upper-air jet stream was found well south of its normal September position, a situation which brings much cold air southward into the United States and causes active frontal and cyclonic developments in southern areas.

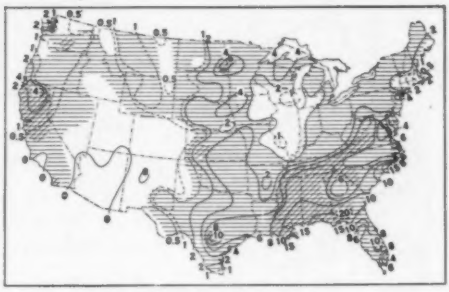
The central trough showed its greatest minus pressure departure from normal over Missouri; the western ridge had its greatest plus departures over British Columbia; and the eastern ridge exhibited above normal pressures along the South Atlantic Coast. Thus, a northwest flow from the western ridge brought cold air into the Great Plains and Mississippi Valley, temperatures ran below normal, and record-breaking minimum readings occurred at many places with unusually heavy snows for September in the mountains.

To the east of the trough, air flow was from the southwest for the first three weeks of September with the result that many new date maximum marks were set east of the Appalachians. The Pacific Coast, under anticyclonic control, had abundant sunshine and predominately southerly flow on the western side of the ridge, raising temperatures to record heights on many days to continue the long sway of hot weather on the immediate coastline.

The central trough underwent three interesting phases which dominated the weather over much of



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.



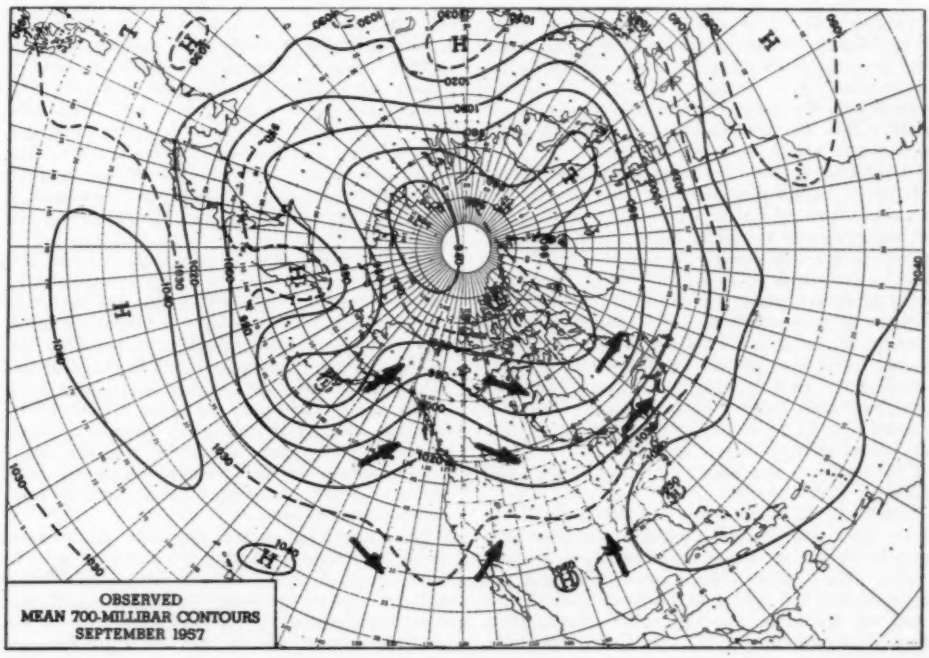
Total Precipitation in inches. USWB chart.

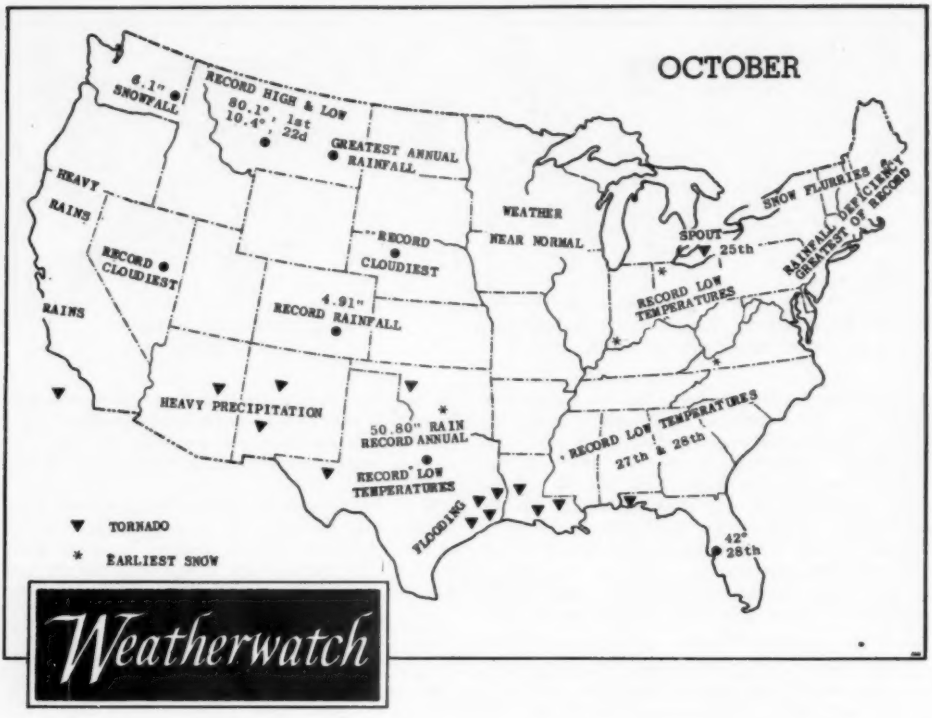
the continent for twenty days. On the 6th a long trough was well established from western Quebec to Texas. With some oscillation eastward and then retrogression westward, it remained the principal feature of all maps until the 12th, creating considerable frontal activity over the Great Plains and the Gulf Coast. On the 13th, 14th, and 15th another trough traveled eastward over the central valleys with abundant precipitation. Again on the 18th a marked trough extended from Hudson Bay southwestward to central California. During the succeeding days the center of the upper-air cyclone remained in position over Ontario as the pendulum-like trough swept slowly eastward, pivoting from the center in Canada, until it cleared the Atlantic Coast on the 26th.

A marked reversal of the circulation pattern took place during the last week of September. On the 24th the western ridge commenced to move eastward in the wake of the trough now nearing the Atlantic Coast. Two days later the ridge dominated

(*Continued on page 210*)

The upper-air map below shows the pattern of air flow for January at about 10,000 feet, on which the average weather largely depends. The contours lines represent the mean height of the 700 mb. pressure level. Figures are in tens of feet: 1020 = 10,200 ft., 980 = 9,800 ft., etc. USWB chart.





Weatherwatch

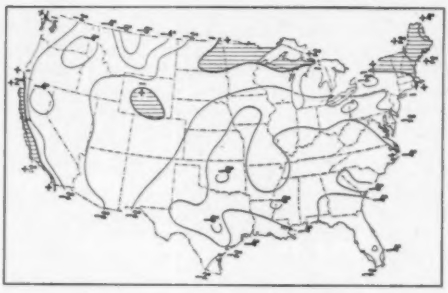
October was a cold month in the United States. A combination of high pressure over most of Canada and low pressure over central and southern United States stimulated a southward transport of cold air masses with the result that many new records for early season low temperatures and early snowfalls were set at widely separated locations.

A principal key to the circulation was the location of the jet stream over the Gulf States during the greater part of the period, a position far south of its normal path over the Great Lakes region. Furthermore, the index of westerly flow reached an all-time low for an October of the past 20 years. The blocking ridge over western Canada split the Pacific jet stream in two channels. The southern branch plunged southeastward from California to the Gulf States. This low latitude position of the jet prevented warm Gulf air from pushing northward with any consistency, and the blocking action of the ridge on the West Coast of Canada prevented any steady movement of warm Pacific air inland. The interior of the continent was open to the free flow of cold polar air from Canada.

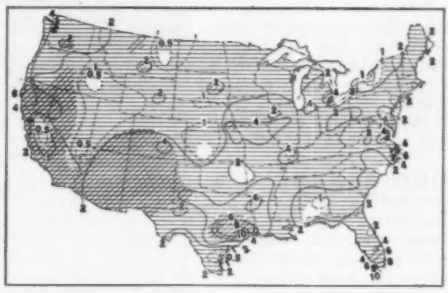
The mean upper-air maps for September and October show some general similarities, but the latter month brought important developments and movements. The blocking ridge in western Canada was more intense and spread its influence much farther east. At the same time the trough directly south over California was more pronounced and influential in steering air streams. Over the Plains and Mississippi Valley a small ridge built up as anticyclones tended to move southeastward out of Canada. Probably the most significant development was the movement of the trough, over the Mississippi Valley in September, to a position between Cape Hatteras and Bermuda in October. The Icelandic low at the northern end of the Atlantic trough underwent great deepening and dominated a swift air flow over the North Atlantic during the month.

Sea level barometric pressure over Canada was much above normal from the Pacific to the Atlantic. Over northwestern British Columbia the departure was plus 8 mb. and over western Ontario as much as 7 mb. with plus values reaching southward to the Gulf of Mexico. The coldest areas in this cold October were found over the Southern States from Oklahoma and Texas eastward to the Atlantic Coast. Averages were six degrees below normal at many locations. The presence of cold air gave low nighttime readings, and the extensive cloudiness from cyclonic activity prevented daytime readings from reaching normal marks.

The precipitation pattern illustrates the influence of the jet stream in causing above normal precipitation along its track. From northern California southeastward to the Texas Gulf coast rainfall was much above normal as the confluence zone of the jet drew moist Pacific air over the Southwest. Of



Departure of Average Temperature from normal in degrees Fahrenheit. USWB chart.

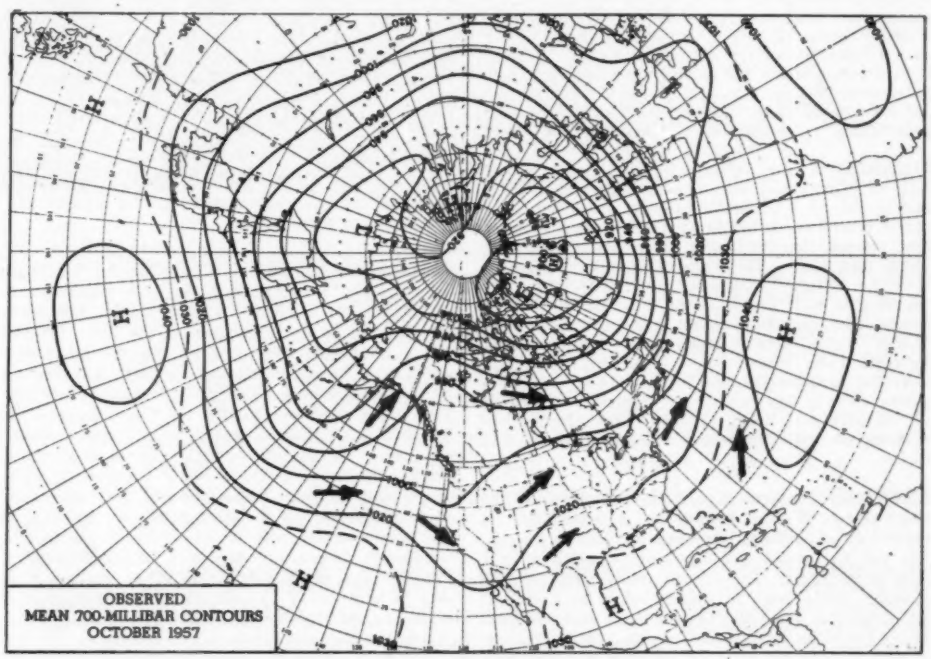


Total Precipitation in inches. USWB chart.

special note were the two tropical storms which formed off the western Mexican coast and moved northward, supplementing the upper-air moisture supply. Over east Texas the onshore movement of Gulf air again brought excessive rains to parts of the Lone Star State. Aside from the Hatteras and Chesapeake Bay areas, where a small coastal storm dropped excessive rains on the 5–6th, it was generally dry. In the Northeast additional deficits were piled on top of the already record string of drought months. At Boston the first ten months of 1957 were the driest January–October period since 1818, and at Providence since 1832.

A TRANSCONTINENTAL STORM—The major storm of the month developed on the 20th in an extensive upper-air trough which had two widely-separated centers: one over Baffin Land in the Arctic, the other far to the southwest over central California. At noon on the 20th a surface low of 1000 mb. (29.53 inches) was centered in Nevada and a strong high of 1040 mb. (30.70 inches) was appearing in the Canadian Northwest. These two systems dominated the weather scene for the next ten days. The low center moved rather slowly over the Plateau and Rockies to emerge on the Plains in western Kansas by noon of the 22nd. Thereafter, the Canadian anticyclone fed cold air into the circulation and the development of the wind rush around the center was rapid. Its forward movement accelerated considerably, speeding from eastern Missouri at noon of the

(*Continued on page 210*)



September (*Continued from page 207*)

the entire Mississippi Valley with a surface anticyclone of 1035 mb (30.56 inches) crested over the Great Lakes area. Now a western trough-central ridge-eastern trough regime prevailed—a temperature reversal followed with much above normal readings in the Plateau, Rocky Mountains, and western Plains and below normal readings east of the Mississippi.

MONTANA SNOW—An unusual snow situation developed in western Montana on the 17–18–19th of September as a trough, followed by an energetic anticyclone with deep cold air, swung southeastward over the central Rocky Mountains. At Helena, Montana, snow commenced on the evening of the 17th and continued with varying intensity until after midnight of the 18th. The total fall at the Weather Bureau station was 13.4 inches. Temperatures on the 18th ranged from 27° to 41°. The 9-inch maximum measured on the 18th was a record depth for any September, as was the total 24-hour amount. Only one other September has had more total snowfall: in 1925 a total of 14.1 inches fell during the month. In some parts of the city the total depths on 18 September reached 15 inches, causing extensive damage to trees, power lines, and communications.

CARRIE—The most intense hurricane of the season formed about 2 September in the Cape Verde region off the African Coast. The ship "African Star" encountered the storm with 80-knot winds on the 6th. By the 9th an aircraft fix was obtained 1,000 miles east of Puerto Rico when winds had reached 160 mph. The center moved in a northerly, then northwesterly direction to a point about 220 miles north of Bermuda on the 17th. Then followed an abrupt recurve to the east and east-southeast which moved the dangerous circulation into the central North Atlantic. In all, CARRIE was under survey as a tropical storm for 24 days, traveled six thousand miles, and had 62 advisories issued about its peregrinations. On the 21st CARRIE was blamed for the sinking of the German windjammer training ship "Pamir" with the loss of nearly 80 lives.

DEBBIE—A low pressure trough in the central Gulf of Mexico had been observed for several days, and on the 7th a tropical depression developed. The center moved north-northeastward at about 15 mph. and crossed the coast near Fort Walton, Florida, about 1000 CST. The highest winds were reported from the Tampa-Tallahassee coastal strip with gusts reaching 50 mph. and a steady wind at 30–40 mph. Storm tides reached 2.5 feet above normal at St. Marks. Local flooding occurred, but without major damage. The storm center continued northward near the Alabama-Georgia border into eastern Tennessee where it lost identity. The main contribution of DEBBIE was heavy rainfall. Crawfordville had 9.19 inches and Tallahassee, a 3-day total of 6.82 inches.

ESTHER—Tropical storm ESTHER formed in the southwestern Gulf of Mexico on 16 September. It moved in a northerly direction at about 12 mph., but did not attain full hurricane strength at any time in its career. The central portion of the storm, a rather diffuse area of squally winds as it crossed the coastline, reached the mainland near Morgan City, Louisiana, about 0600 on the 18th. Highest surface winds were observed to the eastward: Pensacola, Florida, had 52 mph. from the south with gusts to 75 mph. Squalls and heavy rains occurred in advance and to the east of the central storm area and persisted along the Mississippi and Alabama coasts after the storm area had passed. Heavy amounts included 11.31 inches at Burrwood, Louisiana, and 10.31 inches at Biloxi, Mississippi.

FRIEDA—This storm was first identified in its formative stage on 21 September as a squally area with an ill-defined wind circulation between Bermuda and Hispaniola about 800 miles east of Miami. At first the center moved in a westerly direction toward Florida, but then swung northeastward along the Atlantic Coast well offshore. After recurving northeastward, FRIEDA intensified and winds were estimated at 70–80 mph. when it was directly east of the Virginia Capes on the 24th. It passed west and north of Bermuda, continuing as a dangerous storm in the North Atlantic shipping channels.

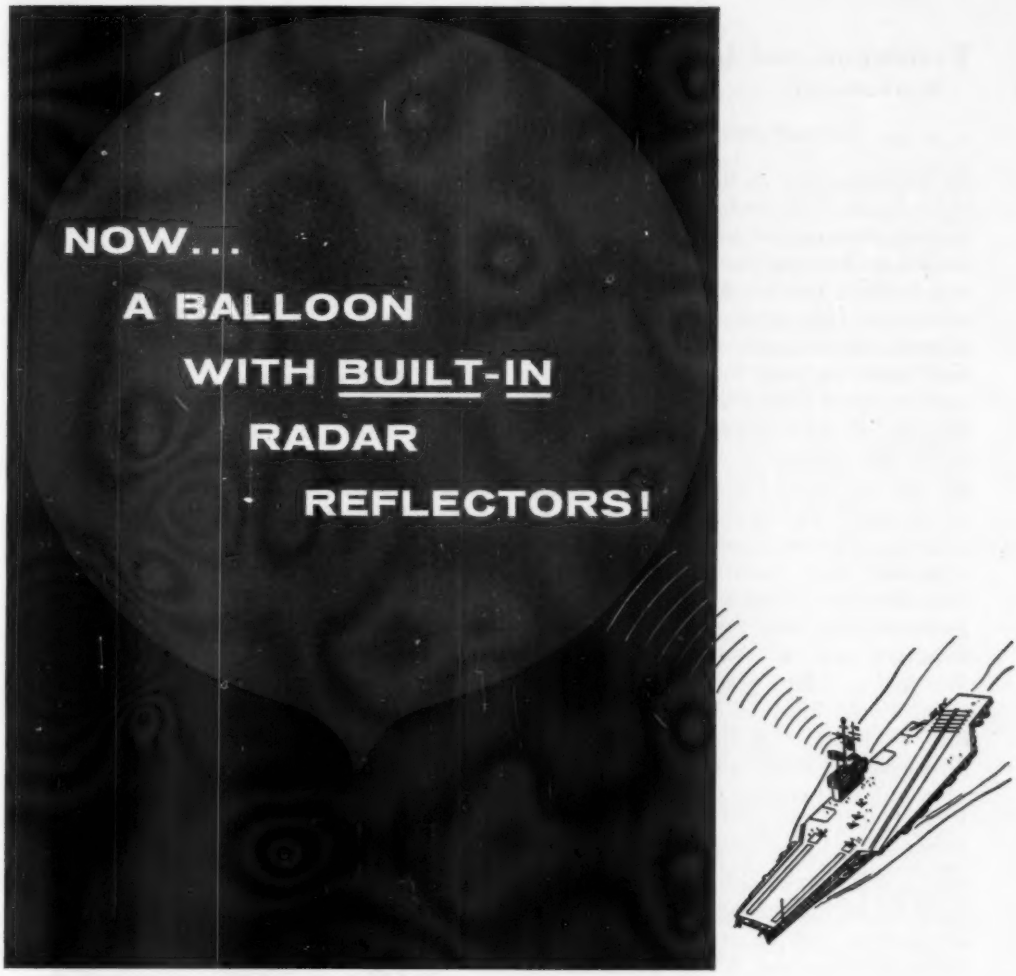
October (*Continued from page 209*)

23rd, to southeastern Ontario on the 24th, and to the southeastern coast of Labrador on the 25th.

The following anticyclone, which developed a central pressure of 1045 mb. (30.85 inches) on the 22–23rd in northern Saskatchewan, moved steadily south-southeastward to Oklahoma by the 27th where the central pressure was still of great magnitude for the latitude and season, 1038 mb. or 30.65 inches.

The cold air accompanying this great anticyclone set many early season minimum temperature records and brought some sections their earliest snowfalls of modern record. Sub-zero readings were experienced in northwestern North Dakota. Southward into Texas and eastward to Florida a freeze was experienced. Waco, Texas, had 28°, Mobile, Alabama, 32°, and Tallahassee, Florida, 35°. A light snowfall in central Oklahoma was the earliest of record. In the Chicago area 2 to 5 inches fell on the 26th, and 5 to 7 inches in northeastern Ohio on the 27th. Snow flurries extended eastward to the Atlantic and southward to New Jersey.

CHESAPEAKE BAY STORM—An indefinite low pressure area persisted over the Southeastern States after the passage of a small tropical low from the Gulf inland over Alabama on the 2nd. On the 5th a circulation developed off the Florida Coast and moved directly northward. Its path was blocked by a sprawling high over Quebec and New England. The center deepened quickly off Cape Hatteras to 992 mb. (29.30 inches) and a steep gradient developed over the Middle Atlantic and southern New England shores as northeast winds exceeded 50 mph. at exposed locations. This was the first semblance of a northeaster on the Atlantic Coast this season. The storm center was forced to curve northwestward over Chesapeake Bay and into southwestern Pennsylvania, giving good rainfall to an area that was in great need of additional moisture for soil replenishment and for facilitating fall plowing. Totals in the Bay area reached four inches.



Tracking weather balloons by radar is basic to U. S. Navy meteorological work. Until now, the best method of making a balloon visible to radar was to attach a trailing reflector . . . expensive, heavy, and hard to launch from shipboard.

To solve this problem, Dewey and Almy has recently developed a balloon with internal, integral reflectors. Thin aluminum strips—dipoles—are attached to the inside surface of the balloon. Radar waves contacting these reflectors bounce back to be seen as blips on the radar screen.

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Washington and Jefferson Snowstorm

(*Continued from page 188*)

his honeymoon late on the 26th, the evening of the day on which the big snow commenced. A light snow commenced, and soon so increased in intensity that the bridal couple were forced to abandon their carriage at Blenheim, about eight miles from Monticello, and to pursue the remainder of the way on horseback over a mountain trail, all the while the storm increased in fury, making progress very difficult. As his daughter in later years related, "they arrived late at night, the fires all out and the servants retired to their houses for the night. The horrible dreariness of such a house, at the end of such a journey, I have often heard both relate."

In his *Garden Book* entry for 26 January Jefferson made note: "the deepest snow we have ever seen. in Albemarle it was about 3. f. deep." In later years he referred to this storm several times as exceeding anything that he recorded in his regular *Weather Memorandum Book,* which commenced in 1776 with the purchase of a thermometer on 1 July at Philadelphia.

The writer happened across another reference to this storm which confirms the measurements of Washington and Jefferson and also indicates that the snow pattern was quite similar to that of the "Knickerbocker" storm of 1922. In the columns of the Philadelphia *United States Gazette* for 27 June 1818 appeared a letter recalling big storms and severe winters of the past. It was written by a resident of Winchester, Virginia, at the northern head of the Shenandoah Valley, and originally appeared in the *Winchester Gazette.* In 1772 the correspondent remembered:

The fall of this present winter until the 27th January, the most pacific winter ever known since the memory of man. On the 27th and 28th of this month there fell a snow exceeding all ever known for the space of a hundred years. I measured it and it was 2 feet 9 inches deep.

Contemporary weather reports from farther north indicate that the snow canopy of 1772 was much like that of 1922 in that the very deep snowfall did not reach much farther north than the Mason-Dixon Line. Good instrumental records for 1772 are at hand for Philadelphia. At 0900 on the 27th of January the temperature was 18°, wind northeast, and barometer 30.50 inches—it commenced to snow an hour later. After a stormy night the snow had ceased to fall by 0900 on the 28th, and the total snow accumulation was not considered noteworthy.

At Newport, Rhode Island, snow fell on the 27th with a high wind from the north with the temperature remaining below 20° all day. At Salem, Massachusetts, "some snow" and excessive cold (8° at sunrise of the 27th) were recorded, but no mention of any snow accumulation. At Falmouth, now Portland, Maine, a weather diarist noted that there were no deep snows in January 1772 although it had snowed frequently during the month.

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Satellite

(*Continued from page 186*)

improvement in short-range weather forecasting is possible.

Longer-range forecasts may be assisted materially. The large-scale cloud patterns that characterize the major cyclone families should give good information on the state of the general circulation, supplementing data from the regular meteorological network, which become discouragingly sparse in some of the more critical regions. This added information could conceivably extend the period over which reasonably accurate forecasts can be made.

Perhaps the greatest improvement in forecasting will come about, not directly as a result of seeing the weather over the whole globe, but as a result of gaining an understanding of the global relations of weather systems. To explain better what is meant, let us simplify a meteorological chain of events. Typically, the storm that might affect the weather of New York two days hence is brewing today in the Gulf of Mexico. Its strength and destination may be controlled by events in the Caribbean. These Caribbean events may be influenced by earlier occurrences in the Southern Hemisphere. It is easy to see that any attempt to trace back a meteorological chain of events leads rather promptly to events occurring over parts of the globe where regular observations are not easily available. One of the reasons for the establishment of camps all over Antarctica during the International Geophysical Year is to collect the weather data that will show the influence of the Antarctic area on the weather of the world. While satellite "television" is hardly a substitute for these careful observations, it can serve many of the same purposes.

The question naturally arises whether the information to be gained is worth the tremendous cost of launching a television satellite. No real answer is possible until it is tried. The United States now has a satellite ready for firing that will send back images of the clouds of the atmosphere with definition better than 10 miles. After the results of this experiment have been analyzed, we will be in a position better to decide whether the cost of more and better television satellites can be returned in benefit to mankind.

Airborne Radar

(*Continued from page 192*)

connected with equipment malfunctions or an inadequate understanding of the limitations of the device. It might be interesting to point out at this time with respect to equipment malfunction, that the mechanical reliability of the equipment is comparable to other units of similar complexity.

The vast majority of the 900 radar reports which are classed in the favorable reaction category have remarks and statement indicating enthusiastic and wholehearted acceptance of the radar as a storm avoidance tool. Such comments as "best thing since four wheel brakes," "greatest invention since the airplane," and others in a similar vein are commonplace. Many of these reports are quite specific as to what the pilot would have done had he not been equipped with radar. For example, "would have turned back and landed," "would have detoured 300 miles south," "flight through the area impossible without radar," and many others. Inasmuch as these reports are filled out by the flight crews, it is felt that this, at the present time, is the best and most representative measure of radar's success.

In conclusion it should be pointed out once again that to assign actual dollar values upon radar installations at the present time is impossible because of the factors mentioned. In spite of these difficulties, this study shows that there is certainly some evidence of radar paying its own way economically. This evidence includes a sharp down trend in static discharges after radar is installed and a reduction of 80 per cent in unusual incidents reported by flight crews. The graphs indicate a steady decrease in number of turbulence incidents, a down trend in the number of minutes involved in turbulence delays, and a marked reduction in the amount of turbulence delay for each incident reported. Last but not least, the flight crews' comments regarding the use of airborne storm avoidance radar in thunderstorm conditions show that unquestionably the device is definitely contributing to increased safety, passenger comfort, and schedule reliability on United Air Lines.

Degree Days

(*Continued from page 201*)

Bureau now, work by many people has shown that there is a distinct long-range trend in weather, and that there is evidence that current weather normals now in use are not the best figures we could use. 2. The project on long-range weather forecasting will tell us with what reliance we can accept the various types of forecasts which are offered from time to time. It has been stated that the industry is probably now buying various types of weather service in an amount exceeding the probable size of the proposed long-range weather project and may be buying even more of this type of service in the future. 3. The API project will convince the weather people that the problem of long-range temperature forecasting is one of significant interest to the petroleum industry and will tend to direct their thinking in such a direction. 4. The project will give us some concrete idea of whether or not we have some chance of developing a really improved forecast by sponsoring certain types of fundamental work which are definitely in need of support and are not supported elsewhere. 5. The API sponsored project will probably develop a somewhat improved forecasting technique for our purposes as compared to any now currently available.

Research projects are generally evaluated on the basis of two factors: 1, the probability of success, and 2, the value of the results if the research is successful. The API project should make the above contributions with a high probability of success, and these should be worth the cost of a project. Beyond this we have the intriguing possibility that a very substantially improved method for forecasting the weather may be found.

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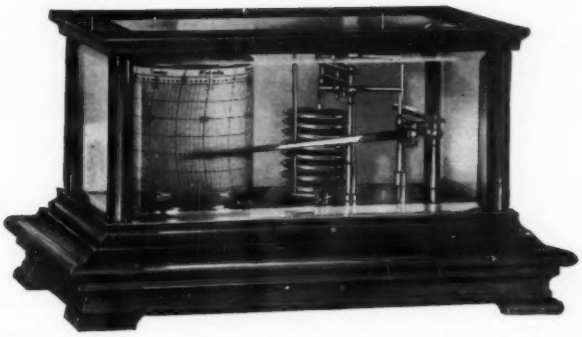

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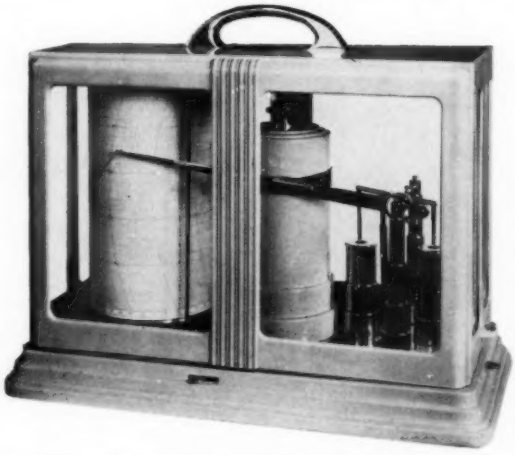

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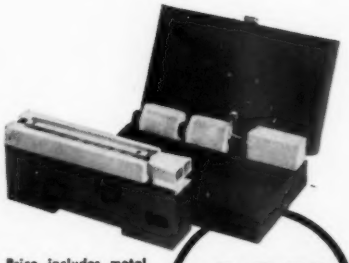

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